NASA
Technical
Paper
2448
C.1
March 1985

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# A New NASA/MSFC Mission Analysis Global Cloud Cover Data Base

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NASA
National Aeronautics
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**Scientific and Technical**
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# A NEW NASA/MSFC MISSION ANALYSIS GLOBAL CLOUD COVER DATA BASE

## INTRODUCTION

Cloud cover is a key element in the research strategy of the U.S. Climate Program. Cloud information is needed to develop an understanding of the role played by clouds in the radiation balance and to aid in the parameterization of clouds in climate models.

Clouds are also a key factor to be considered in the planning of remote sensing missions of the Earth's surface. Depending upon the extent and thickness of a cloud and upon the wavelengths used by the spaceborne sensor, a cloud has effects on the measured radiation ranging from slight attenuation to total absorption. The complexity of modern sensing systems, with wavelengths in the visible, infrared, and microwave, necessitates detailed information on expected cloud cover to permit intelligent planning and studies. In an earlier recognition of the need for a global cloud data set, the Atmospheric Sciences Division at the Marshall Space Flight Center (MSFC) sponsored the development of a global data bank of cloud statistics [1] and computer techniques to utilize the statistics in various simulation studies [2]. This effort employed only standard ground-based cloud observations.

Concurrent with these studies, MSFC also sponsored the development of another data bank [3,4]. This data bank, known as the 4-D Atmospheric Model, contains means and variances of atmospheric pressure, temperature, water vapor, and density from the surface to 25 km above the Earth. Related computer programs were also written to permit the use of this data bank in specifying atmospheric profiles for any latitude, longitude, and month of the year.

By using the worldwide cloud cover statistics and the simulation procedure, it was possible to provide an evaluation of the consequence of cloud cover on Earth-viewing space missions or receipt of solar radiation for individual target areas of swaths over small areas.

Although this earlier data set has received extensive use, it has some major limitations. The number of cloud climatic regions was limited by data volume handling capability and by the amount of suitable data available. The entire United States, for example, is effectively covered in only four or five regions. Also, each region is assumed to be completely homogeneous. That is, the base station cloud distribution applies everywhere within that region. The cloud climatologies for nine of the SH regions were taken as being seasonal reversals of similar NH regions. For some oceanic regions, where representative data could not be obtained, statistics were modified from those of other regions based upon climatological considerations. The satellite-derived data base for the conditional statistics is generally weak. It was necessary to compute conditional probabilities on a seasonal basis to produce an adequate sample size for statistical manipulations. The inconsistency between ground-observed basic or unconditional statistics and satellite-observed conditional distributions has introduced uncertainties in the combined utilization of the two data bases.

The techniques for changing the cloud distributions to make then applicable to larger area sizes, temporal separations other than 24 hr, and spatial distances other than 200 n.mi., are all theoretical and have not been adequately verified. Finally, the original model is more than 15 years old, and much better data have now been acquired.

## CLOUD DATA AVAILABLE FOR NEW DATA BASE

An extensive investigation revealed no suitable summarized or statistical cloud distributions and only one source of cloud observations that provides global coverage and diurnal variation in a manageable volume. This is the 3D NEPH Automated Cloud analysis prepared by the Air Force Global Weather Center [5,6]. Archived SMS/GOES VSSR data do not provide global coverage and contain eight observations daily from both positions (east and west) only since September 1978 [7]. The polar orbiter satellite data provide global coverage, but only daily hemispheric polar stereographic mosaics are archived [8]. The 3D NEPH Analysis, on the other hand, though possessing some limitations in cloud typing [9] which are minimized by using total measurements and other known shortcomings [10] provides the only global coverage of cloud cover amounts at frequent time intervals. These data are directly applicable to mission simulations and for other endeavors.

## 3D NEPH ANALYSIS

The 3D NEPH Analysis, a global cloud analysis, is prepared eight times (00Z, 03Z, 06Z, ...) daily by the Air Force Global Weather Central (GWC), Offutt Air Force Base, Nebraska. In the past, it was prepared only four times daily for the SH. The analysis, made from all available cloud data, includes satellite, aircraft, and ground/ship observations. These observations are fitted into a coherent global cloud structure through a scheme that has been fully described by Coburn and by Fye, which largely eliminates the risk of incorporating erroneous data or interpreting snow or sand as clouds. The analysis encompasses 15 altitude layers and includes 22 parameters on a fine mesh grid (approximately 25 n.mi. spacing at 45 deg latitude).

The 3D NEPH Analysis has all the attributes required for adequate mission simulations except that it is too voluminous to handle. Fortunately, the data processing at the archiving location reduces the volume to a manageable amount.

## 3D NEPH PROCESSING AT ENVIRONMENTAL TECHNICAL APPLICATIONS CENTER

The 3D NEPH Analyses are archived at the Environmental Technical Applications Center (ETAC), Asheville, North Carolina. There, the data are arranged in two files:

1) Box File – Each box is a 64x64 square grid array; grid spacing is approximately 25 n.mi. at 45 deg latitude. Sixty boxes cover one hemisphere. One tape contains data for 1 year-month for one box. For example, one tape contains January 1976 data for one box.

2) Multiple-Purpose Simulator (MPS) File – The Box File data are reduced to the MPS File as follows:

a) Nine-point smoothing changes the grid spacing to approximately 50 n.mi. at 45 deg latitude.

b) Only seven parameters are included: high, middle, and low cloud amounts and types plus total sky cover.

c) Observations are changed from Universal time to local sun time.

In the MPS file there are global cloud cover observations that contain all the attributes needed for application to Earth-viewing simulations, with adequate spatial and temporal densities. Clouds derived from the several observational techniques have been melded into a coherent pattern by the analysis process, and data volume is small enough to be handled with relatively modest resource requirements. The nine point smoothing technique effectively removes any need to assume statistical homogeneity and also voids any requirement to adjust cloud statistics for either spatial or temporal variability by invoking theoretical models.

To further reduce the volume of data, only one parameter – total cloud cover – from the MPS file was selected for the new cloud cover data base.

## ESTABLISHMENT OF THE NEW DATA BASE

In late 1981, with data obtained from ETAC through the National Climatic Center (NCC) of the National Oceanographic and Atmospheric Administration (NOAA), the NASA Cloud Cover Data Base was established. This data base is comprised of one parameter, observed total sky cover, extracted from the MPS file.

As originally received from NCC, a single computer tape holds data for a single month or a single quarter of 1 year, recorded on a daily basis at 3- or 6-hr time intervals at every gridpoint over one hemisphere. With the approximate 50 n.mi. spacing of the MPS file, this constitutes approximately 62,000 data points per hemisphere per individual time interval.

Recorded at each grid point as a two character integer (0 through 20) representing each 5 percent increment of total cloud cover, the data remain a little too voluminous for easy handling. Consequently, the data are changed into single alphanumeric characters before incorporation into the NASA Data Base. This procedure reduces storage needs essentially by a factor of 2. These characters, 0 through 9 and A through L (I is skipped to preclude visual confusion with 1), along with several unique code characters to indicate map boundaries, missing data and the like, now constitute the NASA Data Base character set.

The data are arranged in both quarterly and monthly formats, the former in blocks of 10 records, and the latter in blocks of 255 records. Each record in the quarterly format contains 266 (9 bit) characters, which consists of 255 I-grid points preceded by 11 ID characters in a year/month/day/hour sequence of 2 characters each and a J-grid point of 3 characters. J-grid point numbers range from 3 to 511 in steps of 2 as do I-grid points, the latter of which must be calculated; e.g., the cloud cover at the I/J grid point of 3/9 at 6 a.m. on 2 January 1972 would be found at the first I-grid point datum of the 72 1 2 6 9 record. Records of the monthly format are identical except for containing two additional ending plusses (i.e., "++") used as padding characters. A quarterly format computer tape usually contains 3 months of data of 1 year for one hemisphere while each monthly format tape contains up to 5 years of 1 month for one hemisphere.

Although there are gaps in the data, notably all of 1976 for the NH, the NASA Data Base currently provides daily, 3-hr observed total sky cover for the NH from 1972 through 1977, less 1976. For the SH, there are values at 6-hr intervals for 1976 and 1977 and at 3-hr intervals for part of 1978 and all of 1979 and 1980. More years of data are being added in both hemispheres.

## VALIDATION OF THE DATA BASE

The basic GWC 3D NEPH has previously been described in the literature and has been used for a great many purposes [10,11,12]. However, this NASA data base, although derived from the 3D NEPH has not yet been reported nor widely used.

To ensure that the cloud cover amounts are representative of the real world, several comparisons with ground observed sky cover were made. Figure 1 shows a comparison of single year-month statistics for a few U.S. locations where surface reports were available. The NASA cloud data are from the gridpoint nearest the ground location. U.S. locations were chosen for this comparison since satellite values tend to dominate U.S. portions of the data base.

Table 1 shows cloud cover statistics calculated from the 5 years of this new data base compared with long term ground observed statistics extracted from the previous data base [7].

As in the Figure 1 case, the new statistics apply to the grid point closest to the ground station – in some cases they may be as much as 25 n.mi. apart. This geographic separation, especially in coastal or mountainous areas, might produce different cloud regimes at the two locations. Cloud amount differences can also be expected between the ground climatology versus satellite (NASA) observations and the different period of record of the two samples. Still, there is good agreement between the two data bases. For example, the percent frequency of $\geqslant$0.8 cloud cover at 1500 hr local time for the ground stations averaged 5 percent higher in winter and 10 percent higher in summer as seen in Table 1. Still other investigators have used different validation procedures to verify the basic 3D NEPH data [9,11,12].

Figures 2 and 3 illustrate some hemispheric cloud cover values developed from this new data base. Both figures show a rather dramatic increase in NH cloudiness in 1977. For that year, the mean NH cloud cover was 57 percent. January showed the minimum coverage (49 percent) and July the maximum (62 percent). All available months except mid-1975 were consistently much less for 1972 through 1975 in the NH, yielding a 5-year mean of 46 percent. Mean 1977 coverage for the SH was also 57 percent with the minimum in September (54 percent) and the maximum in February (63 percent). Except for the first two-thirds of 1976, all available months for 1976 through 1980 consistently varied within ±7 percent of this mean value in the SH, yielding a 5-year mean of 56 percent. In general, the data depict scattered conditions in the NH for the first half of the decade of the 70's with a possible trend toward broken conditions during the latter half. However, broken conditions prevail in the SH over the entire last half of the decade.

Large variations were observed in the 1975-76 data, attributable in part to modifications in the automated analysis program. However, such variations scarcely negate the usefulness of this new data base for certain purposes since earlier NH data exhibit strong internal consistency, as does later SH data.

Furthermore, it should be remarked that the 3D NEPH data were derived from a program which had one major objective; i.e., producing operationally significant, Earth-orbital viewing data in a quasi-real-time mode. The program's continual thrust was toward greater and greater clarity of such satellite derived data. Minimal consideration was necessarily given to possible variations between past, current, and future data except as they impacted client missions. In short, as those who have ever been involved in such efforts are fully aware, "yesterday" is passe, "today," paramount, and "tomorrow," problematical though being planned. Archival of data was essentially undertaken in acknowledgement of the waste of data destruction and because such action was only minimally more troublesome or costly than any destruction.

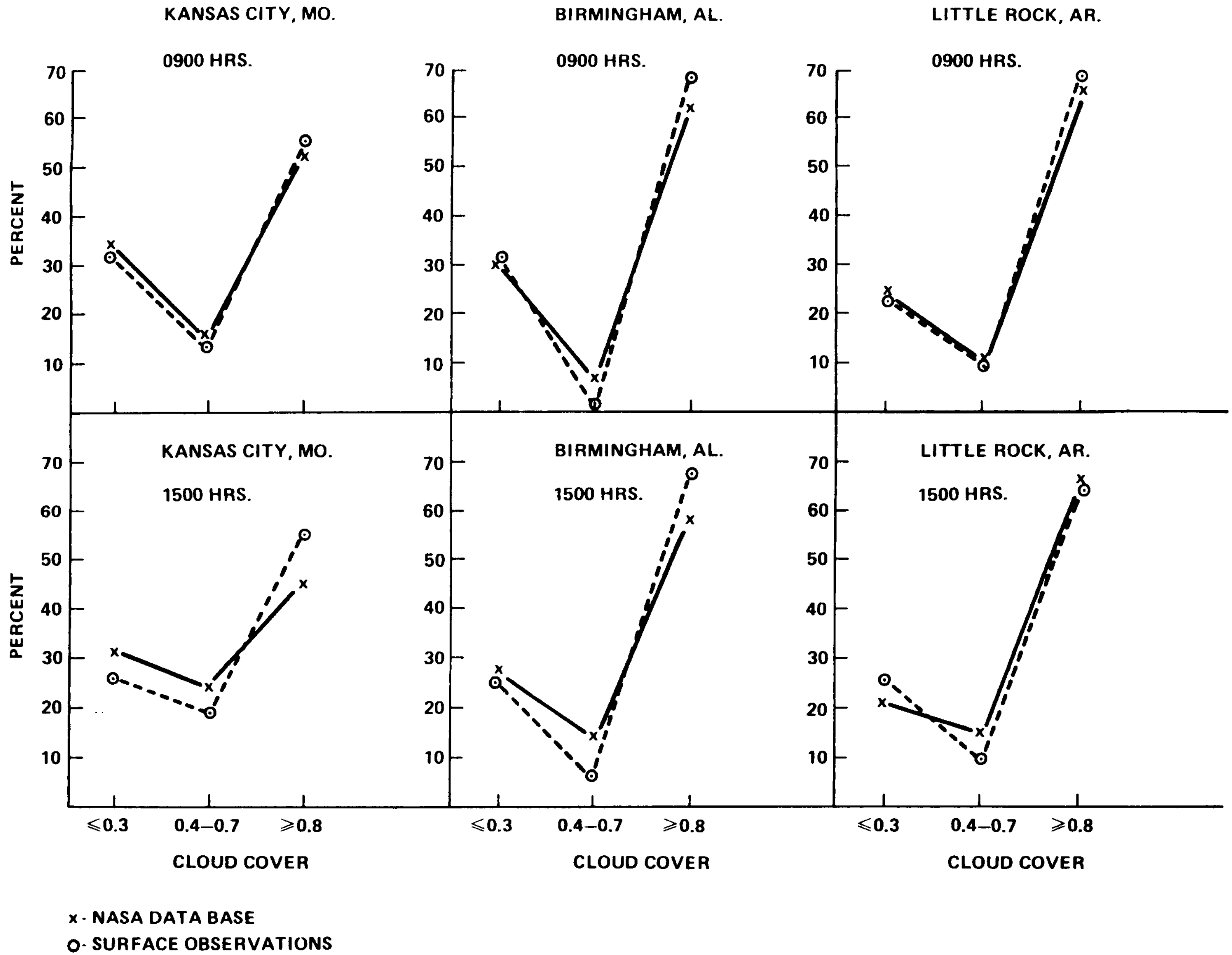


Figure 1. Cloud cover comparison – surface observations and NASA data base, January 1973.

TABLE 1. COMPARISON OF CLIMATOLOGY WITH NASA DATA BASE

PROBABILITY OF ≤0.3 AND ≥0.8 CLOUD COVER AT 0900 AND 1500 HOURS IN DECEMBER AND JULY.

| STATION | DECEMBER ≤0.3 0900 C | N | 1500 C | N | DECEMBER ≥0.8 0900 C | N | 1500 C | N | JULY ≤0.3 0900 C | N | 1500 C | N | JULY ≥0.8 0900 C | N | 1500 C | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DHAHRAN, SAUDI ARABIA | .49 | .37 | .53 | .36 | .22 | .32 | .25 | .28 | .81 | .83 | .84 | .85 | .09 | .01 | .07 | .00 |
| TRIPOLI, LIBYA | .38 | .28 | .33 | .29 | .35 | .35 | .35 | .36 | .89 | .74 | .91 | .83 | .02 | .03 | .03 | .00 |
| ANGELES, LUZON, P.I. | .16 | .13 | .10 | .02 | .58 | .55 | .60 | .59 | .01 | .01 | .01 | .00 | .76 | .74 | .80 | .80 |
| TAMPA, FLORIDA | .39 | .34 | .37 | .30 | .37 | .39 | .36 | .36 | .20 | .20 | .07 | .10 | .38 | .38 | .55 | .40 |
| MOUNTAIN HOME, IDAHO | .22 | .14 | .22 | .15 | .62 | .62 | .60 | .59 | .74 | .66 | .65 | .59 | .11 | .10 | .14 | .15 |
| FORT YUKON, ALASKA | .31 | .48 | .34 | .41 | .55 | .29 | .54 | .39 | .28 | .27 | .21 | .38 | .48 | .37 | .43 | .28 |
| BELLEVILLE, ILLINOIS | .29 | .21 | .28 | .23 | .57 | .65 | .58 | .60 | .31 | .46 | .25 | .31 | .41 | .32 | .36 | .25 |
| BAN ME THUOT, VIETNAM | .07 | .30 | .14 | .26 | .40 | .44 | .36 | .44 | .03 | .26 | .00 | .28 | .51 | .47 | .51 | .38 |
| SHIP D (ATLANTIC) | .13 | .06 | .04 | .04 | .60 | .67 | .68 | .73 | .15 | .32 | .15 | .35 | .61 | .35 | .55 | .32 |
| ADAK, ALASKA | .04 | .02 | .03 | .03 | .71 | .69 | .71 | .73 | .02 | .01 | .03 | .02 | .84 | .87 | .80 | .83 |
| RESOLUTE, NWT, CANADA | .64 | .65 | .50 | .61 | .31 | .08 | .37 | .15 | .20 | .12 | .17 | .13 | .64 | .38 | .66 | .45 |
| FORT KOBBE, CANAL ZONE | .26 | .28 | .16 | .10 | .37 | .27 | .48 | .30 | .03 | .00 | .00 | .01 | .80 | .67 | .82 | .70 |
| BANGALORE, INDIA | .30 | .47 | .26 | .45 | .31 | .18 | .34 | .17 | .00 | .01 | .00 | .06 | .80 | .79 | .77 | .67 |
| SAN FRANCISCO, CALIFORNIA | .32 | .24 | .39 | .26 | .55 | .41 | .46 | .41 | .72 | .35 | .84 | .50 | .16 | .23 | .08 | .18 |
| SHREVEPORT, LOUISIANA | .33 | .32 | .36 | .38 | .53 | .51 | .48 | .46 | .34 | .30 | .27 | .27 | .33 | .34 | .34 | .26 |
| SHIP V (PACIFIC) | .17 | .35 | .18 | .32 | .54 | .32 | .53 | .34 | .16 | .39 | .25 | .48 | .56 | .30 | .52 | .25 |

C = CLIMATOLOGY N = NASA

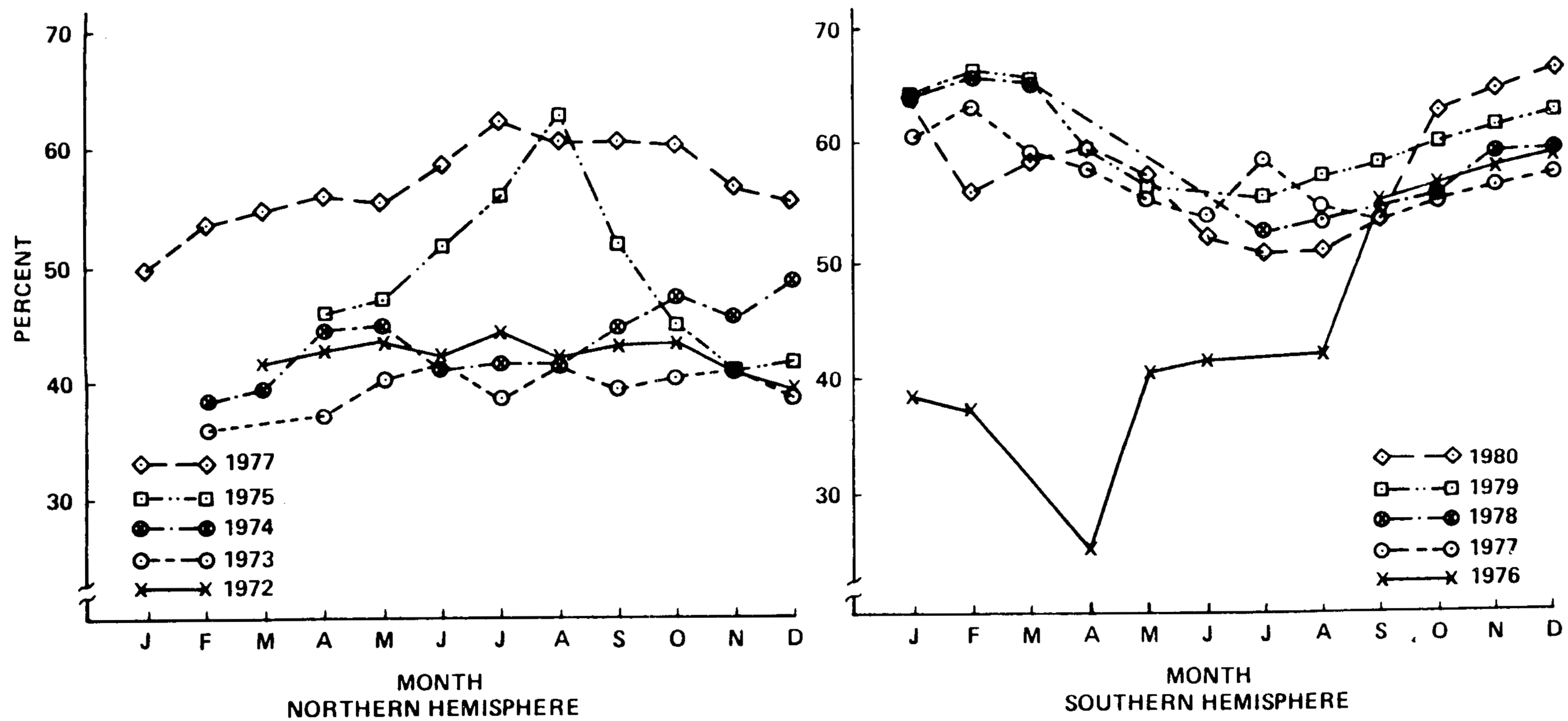


Figure 2. Mean hemispheric cloud cover.

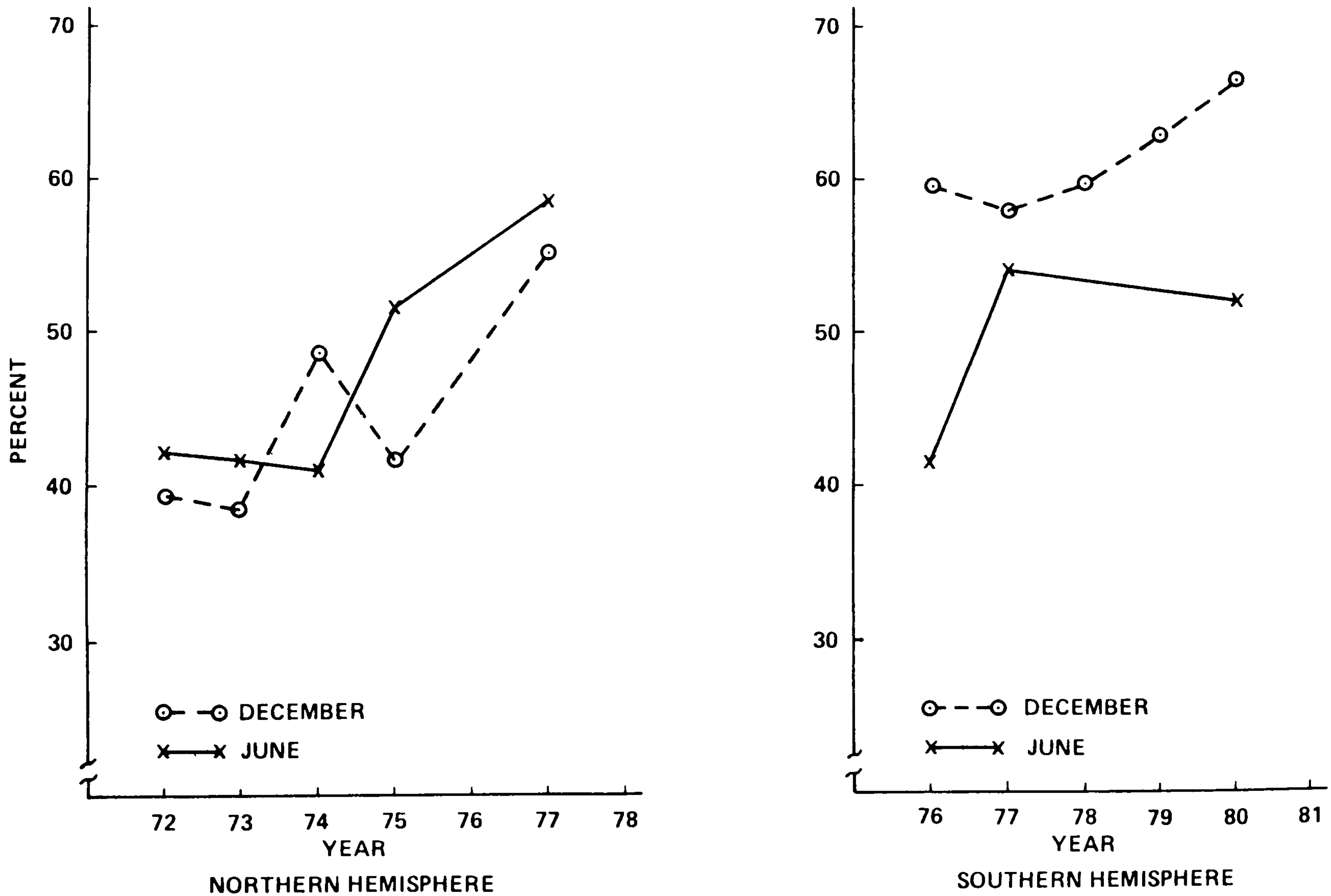


Figure 3. Mean monthly cloud cover.

The current effort is only one of several which have been undertaken in an attempt to revitalize the usefulness of these archived data and is highly appropriate for the eve of a proposed international study of global cloud cover effects on climate. Naturally, because of its nature, discrepancies in the 3D NEPH archive are to be expected. Future investigations of these variations are planned; but, as others have suggested, the 3D NEPH data is probably the best of its kind currently available [12,13]. It is also the authors' opinion, as well as that of many others, that the potential usefulness of the data dramatically outweighs any inherent drawbacks. Presentation of the NASA Data Base is an effort to make the data more immediately available.

## THE EARTH-VIEWING SIMULATION PROCEDURE

The great attribute of this data base in Earth viewing applications is the direct use of observed cloud cover instead of a Monte Carlo selected cloud amount. This is especially advantageous when the Earth target area is larger than the area viewed by the sensing instrument. For example, suppose the desired target area is 1000 x 100 n.mi. and a camera acquires a series of pictures 100 x 100 n.mi. which are pieced together to cover the desired area. To simulate this situation using a statistical cloud cover data base requires a Monte Carlo draw of cloud cover encountered in the initial 100 x 100 n.mi. picture. This first part is a reasonable approach which should give good results for the first picture. For the remainder of the 1000 n.mi. swath, however, the Monte Carlo procedure becomes more complicated and less likely to produce reasonable results – due to the spatial (and sometimes temporal) continuity of clouds. To avoid unreasonable cloud patterns such as alternating clear and overcast in the remaining nine 100 x 100 n.mi. squares, the statistical data base must have additional time and space conditional probability distributions – which induces a further departure from reality.

Earth viewing simulations, using the new data base bypass the time and space conditional probability problem by always using observed cloud cover. Although no missions have yet been analyzed with this NASA data base, the mechanics of the simulation procedure have been developed along with an ephemeris program and a program to locate gridpoints from latitude/longitude coordinates.

To illustrate the simulation procedure, consider, for example, the case described above where it is required to photograph a swath 1000 n.mi. long and 100 n.mi. wide.

1) Step 1 – Locate the gridpoint closest to the center of the first 100 x 100 n.mi. square and the four surrounding gridpoints; i.e., I+1, I-1, J+1, J-1.

2) Step 2 – Calculate the mean cloud cover of those five points for the appropriate date/time and assign that value to the first square.

3) Step 3 – Move 100 n.mi. along the ground track and repeat Step 1 and Step 2. Repeat until all ten 100 n.mi. squares have an assigned cloud cover.

4) Step 4 – Average the ten values from above to obtain a single cloud cover for the entire swath. One minus the cloud cover is the fraction of Earth viewed on the first pass or revolution over the target area. Store this value.

5) Step 5 – Repeat the entire process the number of times in the month or season the actual mission will be flown.

6) Step 6 – Summarize the results to show: (a) The probability of success (where success is defined as photographing some specified percent of the swath) versus number of satellite passes over the target (Fig. 4). (b) Probability versus area photographed for a specified number of satellite passes over the target (Fig. 5).

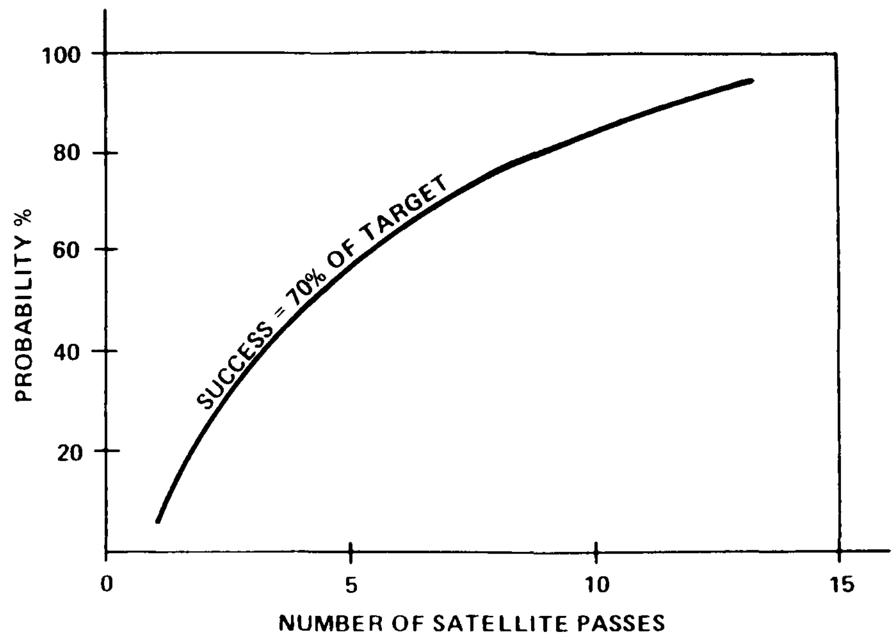


Figure 4. Probability of success.

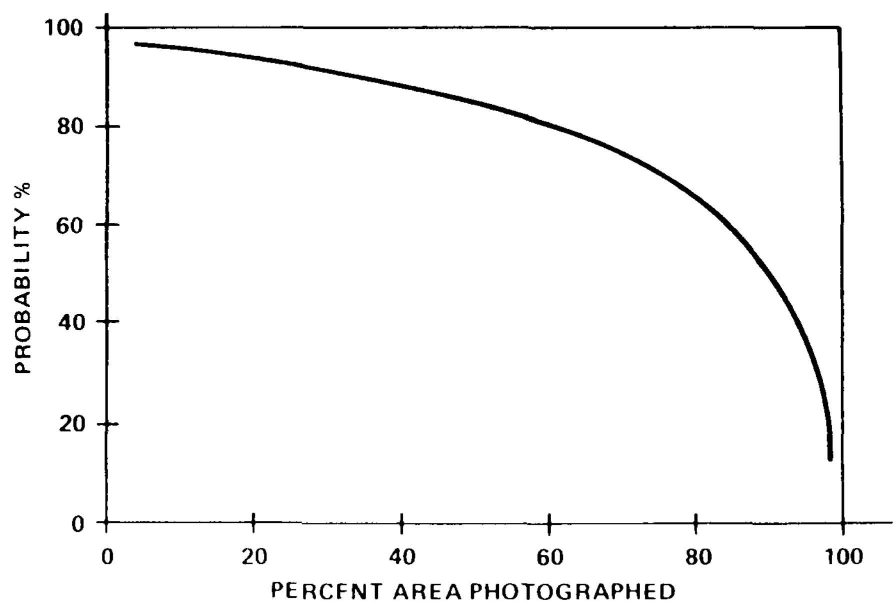


Figure 5. Photographic coverage of target area after ten satellite passes.

While the example specified a 1000 x 100 n.mi. swath, the simulation procedure can be applied to any size area from a single gridpoint to a continent. Also, details as fine as single gridpoints within larger areas can be analyzed. For example, perhaps the mission requirements can be satisfied by incremental photographic coverage, i.e., forming a montage from parts of the area acquired on separate satellite revolutions, rather than acquiring the necessary amount on a single try. In this case, single gridpoints within the area can be cleared on successive passes to contribute to the area coverage. There is enough built-in flexibility to accommodate a wide variety of mission requirements.

## SUMMARY


A unique cloud cover data base for use in climate studies and Earth viewing applications has been developed. This data base, derived from the GWC 3D NEPH Analysis, currently consists of 3-hr observations for 5 years for the NH and 6-hr observations for 3 years with 3-hr observations for 2 additional years for the SH. Cloud cover is given in 5 percent increments at gridpoints approximately 50 n.mi. apart at 45 deg latitude.

Several data validation analyses indicate that the cloud cover values are descriptive of the real world. These analyses included comparisons with ground observed cloud cover for single year-month-times and for long term means.

A number of hemispheric monthly mean cloud cover calculations showed generally less than 10 percent variation for like months across the years, except for mid-1975 and 1977 in the NH and for the first two-thirds of 1976 in the SH. For the NH 1977 year, the mean cloud cover was higher in every month, as it was for mid-1975 – sometimes almost as much as 25 percent higher – than any other year, whereas, for the first two-thirds of the SH 1976 year, the mean cloud cover was almost as much as 35 percent lower than any other year. Other calculations showed generally scattered conditions in the NH over the first half of the 70's decade while generally broken conditions prevailed in the SH over the last half of the decade.

The data base is especially useful in evaluating the consequence of cloud cover on Earth viewing space missions. The temporal and spatial frequency of the data allow simulations that closely approximate any projected viewing mission. The greatest attribute is that no adjustments are required to account for cloud continuity.


## POSTSCRIPT

Subsequent to the inception of this paper's review process, N.A. Hughes' very excellent comprehensive review of global cloud climatologies was published ("Global Cloud Climatologies: A Historical Review," J. Climate Appl. Meteor., Vol. 23, pp. 724-51). Notably Hughes indicated that a 1968 study by J. G. Barnes and D. Chang (Allied Research Associates, NAS5-10478, 92 pp.) implied that satellite and surface cloudiness statistics may be satisfactorily compared when satellite data sets are formulated for approximately 50 km diameter circular areas. He also stated that "total cloud amount is likely to be the most accurately derived parameter." The NASA Data Base is so configured.

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| 1. REPORT NO. | 2. GOVERNMENT ACCESSION NO. | 3. RECIPIENT'S CATALOG NO. |
|---|---|---|
| NASA TP-2448 | | |

**4. TITLE AND SUBTITLE**
A New NASA/MSFC Mission Analysis Global Cloud Cover Data Base

**5. REPORT DATE**
March 1985

**6. PERFORMING ORGANIZATION CODE**


**7. AUTHOR(S)**
S. C. Brown and W. R. Jeffries III


**8. PERFORMING ORGANIZATION REPORT #**


**9. PERFORMING ORGANIZATION NAME AND ADDRESS**

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812


**10. WORK UNIT NO.**
M-480

**11. CONTRACT OR GRANT NO.**

**12. SPONSORING AGENCY NAME AND ADDRESS**

National Aeronautics and Space Administration
Washington, D.C. 20546

**13. TYPE OF REPORT & PERIOD COVERED**

Technical Paper

**14. SPONSORING AGENCY CODE**

**15. SUPPLEMENTARY NOTES**


S. C. Brown: George C. Marshall Space Flight Center, Marshall Space Flight Center, Alabama.

W. R. Jeffries III: Computer Sciences Corporation, Huntsville, Alabama.


Prepared by Systems Dynamics Laboratory, Science and Engineering Directorate.


**16. ABSTRACT**

A global cloud cover data set, derived from the USAF 3D NEPH Analysis, has been developed for use in climate studies and for Earth viewing applications. This data set contains a single parameter – total sky cover – separated in time by 3 or 6 hr intervals and in space by approximately 50 n.mi. Cloud cover amount is recorded for each grid point (of a square grid) by a single alphanumeric character representing each 5 percent increment of sky cover.

The data are arranged in both quarterly and monthly formats. A quarterly format computer tape usually contains 3 months of data for one hemisphere while each monthly format tape contains up to 5 years of 1 month for one hemisphere.

Although there are gaps in the data, notably all of 1976 for the Northern Hemisphere, the data base currently provides daily, 3-hr observed total sky cover for the Northern Hemisphere (NH) from 1972 through 1977 less 1976. For the Southern Hemisphere (SH), there are data at 6-hr intervals for 1976 through 1978 and at 3-hr intervals for 1979 and 1980. More years of data are being added in both hemispheres.

To validate the data base, the percent frequency of $\leq 0.3$ and $\geq 0.8$ cloud cover was compared with ground observed cloud amounts at several locations with generally good agreement.

Mean or other desired cloud amounts can be calculated for any time period and any size area from a single grid point to a hemisphere.

The data base is especially useful in evaluating the consequence of cloud cover on Earth viewing space missions. The temporal and spatial frequency of the data allow simulations that closely approximate any projected viewing mission. The greatest attribute is that no adjustments are required to account for cloud continuity.



**17. KEY WORDS**

Cloud Model
Global Weather
Cloud Statistics
Satellite Meteorology


**18. DISTRIBUTION STATEMENT**

Unclassified – Unlimited

Subject Category 47

| 19. SECURITY CLASSIF. (of this report) | 20. SECURITY CLASSIF. (of this page) | 21. NO. OF PAGES | 22. PRICE |
|---|---|---|---|
| Unclassified | Unclassified | 16 | A02 |

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